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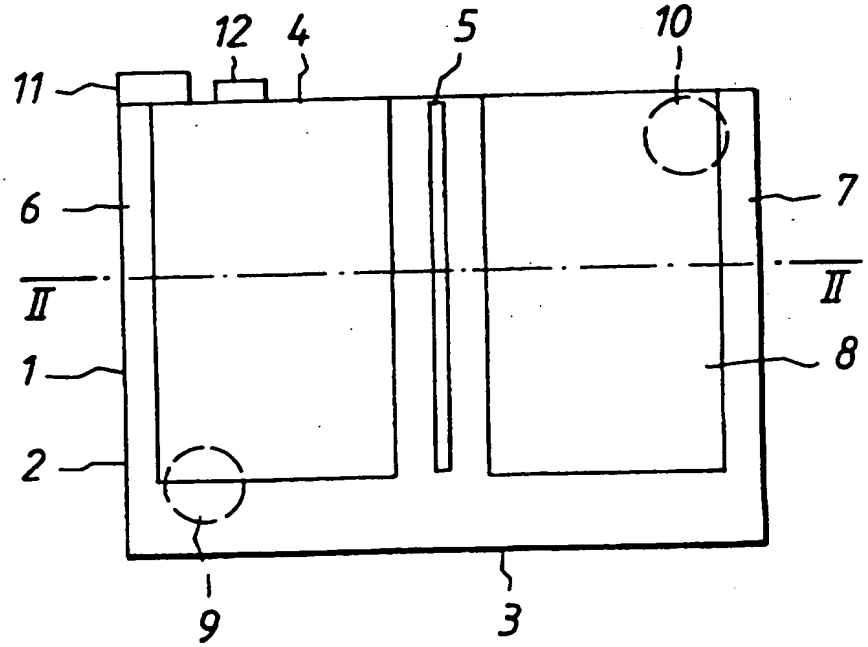
(57) Abstract

The invention relates to an apparatus for electrical purification of water, said apparatus comprising a reaction chamber (1) provided with side walls (2), a bottom wall (3), a top wall (4) and a partition wall (5) dividing the reaction chamber into a first chamber (6) and a second chamber (7), each provided with a mainly vertical electrode (8), the partition wall and the electrodes being disposed at a distance from the bottom wall; an inlet (9) for the water to be purified; an outlet (10) for the purified water; a power source (11) and a gas outlet. According to the invention, the inlet for the water to be purified is located in a wall (2, 3, 4) of the first chamber (6) and the outlet (10) for the purified water in a wall (2, 3, 4) of the second chamber (7), so that the water to be purified can circulate freely from the first chamber (6) into the second chamber (7), washing the electrodes (8) and the reaction chamber (1).



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AN APPARATUS FOR CLEANING WATER

The present invention relates to an apparatus for electrical purification of water as defined in the preamble of claim 1. Moreover, the invention relates to a procedure for electrical purification of water.

In prior art, many types of electrochemical water purification devices and filters are known. Patent specification US 5 227 052 presents a water purification apparatus based on an electrochemical reaction, comprising a reaction chamber with a partition dividing the reaction chamber into two compartments. In each compartment of the reaction chamber there is one plate-shaped electrode, in which the water purification reaction takes place. When electric power to the electrodes in the reaction chamber is switched on, a reaction producing hydrogen, ozone and pure water takes place; at the positive plate electrode, OH^- ions are separated, producing water and oxygen and then ozone, while on the negative electrode H_3O^+ ions are separated, producing water and hydrogen. The partition prevents the gas bubbles formed in the reaction from combining, and the hydrogen produced can be passed out of the reaction chamber. The water inlet is in the bottom wall of the reaction chamber and the water is passed via it into both chambers simultaneously. The water can flow from one chamber to the other under the partition and through holes provided in the partition. The outlet for the purified water is placed in a side wall of the chamber on the same side with the inlet, and the gas outlet is in the top wall of the reaction chamber.

A problem with this apparatus is that the water cannot flow freely in the reaction chamber, with the result that dirt is heavily accumulated on the electrodes, requiring cleansing of the apparatus at short intervals, thus reducing its purification effect and increasing down time.

The object of the invention is to eliminate the drawbacks mentioned above.

A specific object of the invention is to present an apparatus that does not require much cleansing.

Another object of the invention is to present a small-sized apparatus that has a good purification effect.

A further object of the invention is to present an apparatus that produces water having a low degree of hardness.

A further object of the invention is to present an apparatus that allows water purification without chemicals, using a purification reaction that takes place at the molecule level and leaves no detrimental residue in the water. Therefore, no smells or tastes detrimental to water quality are developed in the purified water.

The apparatus of the invention is characterized by what is presented in the claims.

The apparatus of the invention comprises a reaction chamber having side walls, a bottom wall, a top wall and a partition wall which divides the reaction chamber into a first chamber and a second chamber. Each one of the two chambers is provided with a mainly vertical plate electrode, and the partition wall and the plate electrodes are disposed at a distance from the bottom wall. Furthermore, the apparatus comprises an inlet for the water to be purified, an outlet for the purified water, a power source and a gas outlet. The water inlet is placed in a wall of the first chamber, so that the water to be purified can flow freely from the first chamber into the second chamber, washing the electrodes and the reaction chamber. The inlet for the water to be purified may be located in the top, bottom or side wall of the first chamber of the reaction chamber, and, correspondingly,

the outlet for the purified water may be located in the top, bottom or side wall of the second chamber, preferably in the opposite wall, so that the water to be purified will wash the entire reaction chamber as fully as possible. The gas outlet is placed in a different chamber than the outlet for purified water to ensure that the gases produced in the electrochemical reaction will not be discharged via the outlet for purified water but can be recovered and utilized if desired.

Due to the continuous washing, less dirt is accumulated in the apparatus of the invention than in prior-art electrochemical water purification devices. Moreover, the construction of the apparatus of the invention makes it possible to achieve a good purification effect in relation to the size of the apparatus. As the apparatus accumulates less dirt than prior-art devices, no prolonged down time is incurred and the operating costs of the apparatus are low. The invention also allows long-time continuous operation of the apparatus.

Furthermore, due to its simple construction, the apparatus of the invention is economic and easy to maintain.

In the apparatus of the invention, electrochemical purification occurs via a prior-art process. Electric power is supplied to the electrodes in the reaction chamber and the resulting electrochemical reaction is utilized, discharging the ionic charges of the impurities; at the same time, the reaction produces ozone, hydrogen and even ultraviolet radiation. This reaction is so effective that it has a substantially more effective ability to kill bacteria, viruses and microbes than do most chemical purifying agents, such as chlorine compounds, e.g. chlorine. Moreover, the electrochemical reaction covers a considerably wider range than chemical purifying agents,

which do not necessarily have any effect on all bacteria, viruses and microbes. The ozone produced in the reaction dissolves quickly and the purified water contains no ozone.

In an embodiment of the invention, the inlet opening for the water to be purified is of a rectangular shape and is placed in a side wall of the first chamber of the reaction chamber, and the water outlet opening is located in that side wall of the second chamber of the reaction chamber which lies opposite to the inlet, so the water can circulate freely from the first chamber into the second chamber and the electrochemical purifying reaction occurs as effectively as possible on the surface of all electrodes.

In another embodiment, the chambers in the reaction chamber are provided with several plate electrodes, preferably at least two plate electrodes in each chamber. The electrodes may be placed in a mainly parallel arrangement in each chamber. As the reaction chamber is of a rectangular shape, the plate electrodes can be mounted at right angles relative to the walls of the apparatus, preferably at a sharp angle relative to the walls of the apparatus, so the number of electrodes and the surface area on which the electrochemical purification reaction takes place are maximized in relation to the size of the apparatus and the water can circulate effectively in the reaction chamber, washing the electrodes and the reaction chamber. Further, in each chamber separately, the plate electrodes may be placed parallel to each other at a suitable angle relative to the reaction chamber wall, e.g. so that the second chamber is a mirror image of the first chamber. The electrodes may be of a plate-like shape or they may be composed of rod-shaped elements or the like. In an embodiment of the apparatus, the electrodes are of a rod-like shape, placed in rows, preferably parallel rows, the rows being arran-

ged at an angle to the walls of the reaction chamber, preferably at a sharp angle to the walls of the reaction chamber.

The electrodes are made of electrically conductive material, preferably e.g. zinc, copper, carbon, silver, graphite, titan, or the like.

In an embodiment of the apparatus of the invention, all the electrodes are made of the same material. It is also possible for the apparatus of the invention to have electrodes made of two or more different materials; in this case, the purification effect can be adjusted by considering the impurities, the desired purification effect and/or the desired degree of purification.

The electrodes may be attached to the top wall of the apparatus, e.g. to a detachable cover part, in which case they can be lifted up together with the cover for cleansing if required. This allows easier and faster cleansing of the apparatus.

In an embodiment, the bottom wall of the apparatus consists of an electrically conductive bottom plate, which allows a homogeneous electric field to be set up over the whole liquid flow through the apparatus, so that no bypass flow occurs. This enhances the effect of the electrochemical purification. The bottom plate may be made of metal, preferably copper, stainless steel or the like.

In an embodiment, the apparatus further comprises a filter for further purification of the water. The apparatus may be provided e.g. with a reverse osmosis filter, in which case detrimental foreign matter of even the smallest molecular size can be removed from the water. The diffusion shell of the reverse osmosis filter can be so selected that it will only pass substances of a given molecular size through it. In an embodiment, the apparatus may comprise an active carbon filter, which can be used to filter e.g. the water

filtered through the reverse osmosis filter or in general the purified water.

In an embodiment of the invention, the apparatus comprises a centrifugal crystallizing/separating cyclone, into which any water not filtered by the filter is passed and in which foreign matter is crystallized for possible recovery.

In an embodiment, the water purification apparatus is mainly of the shape of a parallelopiped and placed at an oblique angle, preferably a sharp angle, e.g. 45°, relative to the horizontal plane. In this case, the water inlet is below while the outlet for purified water and the gas outlet are above.

In the procedure of the invention for the purification of water, water is supplied into the water purification apparatus, where the water is purified electrically. In the procedure, the water circulates freely in the reaction chamber and, as a result of an electrochemical reaction, ozone and possibly even ultraviolet radiation are produced, while at the same time the ionic charges of the impurities are discharged, bacteria, viruses and micro-organisms present in the water are destroyed and, depending on the electrochemical reaction, metal ions are dissolved. On the whole, the reaction produces pure water and, as a by-product, hydrogen gas. The ozone produced in the reaction is a transient physical state of oxygen and disappears quickly.

From the electric purification apparatus, the water can be passed further into a filter, preferably a reverse osmosis filter. The water can be passed further through an active carbon filter and then taken into use.

In an embodiment for the purification of drinking water, any water not filtered by the reverse osmosis filter (substances having a large molecular size) is passed into a centrifugal crystalli-

zing/separating cyclone and then back to the purification process. The filtered water is circulated again several times in the purification apparatus, so that any foreign matter will crystallize and can be recovered. In an embodiment of the procedure of the invention, drinking water is purified from sea water, producing table salt, among other things, as a by-product.

In the following, the invention is described in detail by the aid of examples of its embodiments by referring to the attached drawing, in which

Fig. 1 presents a cross-sectional lateral view of an apparatus according to an embodiment of the invention,

Fig. 2 presents the apparatus of Fig. 1 as sectioned along line II-II,

Fig. 3 presents a flow chart representing an apparatus according to the embodiment in Fig. 1, used for the purification of drinking water,

Fig. 4 presents an embodiment of the apparatus of the invention, in which the water purification apparatus is placed at an angle of 45° relative to the horizontal plane.

Fig. 1 shows the reaction chamber 1 of the water purification apparatus. The reaction chamber has side walls 2, a bottom wall 3, a top wall 4 and a partition wall 5 dividing the reaction chamber into a first chamber 6 and a second chamber 7, each of which contains mainly vertical plate electrodes 8. The partition and the plate electrodes are placed at a distance from the bottom wall. Moreover, the apparatus comprises an inlet 9 for the water to be purified, an outlet 10 for the purified water, a power source 11 and a gas outlet 12 placed in the upper part of the reaction chamber 1 in the wall opposite to the water inlet, the inlet 9 for water to be purified being placed in wall 2 of the first chamber 6 and the outlet 10 for purified water in the opposite wall of the second

chamber 7, so that the water to be purified is caused to circulate freely from the first chamber 6 into the second chamber 7, washing the electrodes and the reaction chamber 1.

Fig. 2 shows the reaction chamber 1, the side walls 2, the first chamber 6 and the second chamber 7, the electrodes 8 and the bottom wall 3, which is provided with a bottom plate 13. The first 6 and second 7 chambers of the purification apparatus contain a number of plate-shaped electrodes 8 placed parallel to each other at a sharp angle to the reaction chamber walls, which are also mainly parallel to each other. In addition, the plate-shaped electrodes are so arranged that the second chamber is a mirror image of the first chamber. The electrodes may also be of a rod-like shape and placed in rows, which are at a sharp angle to the walls of the apparatus. Fig. 2 further shows the water inlet 9, which is located in a side wall of the first chamber, and the outlet 10 for purified water, located in the opposite side wall of the second chamber.

To purify water by means of the apparatus of the invention, the water is passed in via the inlet 9 into the first chamber 6 of the reaction chamber 1, which contains a large number of plate-shaped electrodes 8. From the first chamber, the water flows freely, circulating under the partition into the second chamber 7, from where the purified water is removed via the outlet 10 and the hydrogen gas is removed via the gas outlet 12. When the water comes into contact with the electrodes, it undergoes an electrochemical reaction, during which the ionic charges of the impurities are discharged, bacteria, viruses and micro-organisms present in the water are destroyed and, depending on the electrochemical reaction, metal ions are dissolved.

Fig. 3 shows an embodiment of the apparatus

of the invention for the purification of drinking water from sea water. The figure shows a water purification apparatus with a power source 11. The water to be purified is supplied into the purification apparatus via the inlet 9, further into the reaction chamber 1, first into the first chamber 5 and then into the second chamber 7, where the water circulates freely under the partition and between the plate-shaped electrodes. The water is removed from the purification apparatus via the outlet 10 into a reverse osmosis filter 14, which is provided with an ultrasonic device (17) to prevent undesirable crystallization. The diffusion shells of the reverse osmosis filter are so chosen that only molecules smaller than a given size can pass through the diffusion shell. The water filtered through the reverse osmosis filter 14 is passed further out into an active carbon filter 15, from which pure drinking water is obtained. Substances and liquid having a larger molecular size are passed from the reverse osmosis filter 14 into a centrifugal crystallizing/separating cyclone 16 and back into circulation into the water purifier and into the reverse osmosis filter 14. When the amount of filtered water obtained via the reverse osmosis filter reaches about six times the total volume of the apparatus, the quantity of salt contained in the sea water in circulation has increased so much that its volume as a weight percentage exceeds the supersaturation salt content (25%), resulting in crystallization and sedimentation of the salt. Since salt has a higher specific weight than water, it sinks to the bottom of the cyclone, from where it can be recovered as a secondary product. If premature crystallization occurs, it is possible to provide the water purifier with an ultrasonic device, mounted on a suitable point, e.g. on the reverse osmosis filter, to prevent the crystallization of salt.

The apparatus of the invention can be opera-

ted with alternating current, direct current or pulsating direct current. The voltage used may vary from a low voltage to high voltages. Preferably a voltage of about 1 - 36 V or even 40 V is used, in which case the voltage involves no danger and the apparatus need not be insulated.

The apparatus of the invention is applicable for use for a variety of water purification purposes. It can be used for the purification of the water in swimming pools, swirl pools etc., reducing the need for purifying agents. Thus, the invention also reduces waste water problems. The low hardness of the water can also be utilized in thin-film evaporators, reducing the amount of energy needed.

EXAMPLE 1

An apparatus as provided by the invention was used for the purification of the water in a swimming pool. The swimming pool was continuously used in the normal way and the water purifier of the invention was occasionally in operation. Sample 1 was taken when the swimming pool had been in normal use and the purification apparatus had been in operation. Sample 2 was taken five weeks after sample 1. The purification apparatus was in operation between the samples, yet not during the last week before sample 2 was taken. Sample 3 was taken four weeks after sample 2. Between samples 2 and 3, the purification apparatus was not in operation at all. Table 1 presents the results of analysis of the water samples.

As can be seen from Table 1, no bacterial growth took place in the swimming pool although the apparatus was not in operation at all for a week before the taking of sample 2, nor even after five weeks (sample 3) without operating the apparatus. Thus, after a certain level of ionisation with certain metals had been reached, it was not necessary to operate the

water purifier at all except to maintain the level of ionization of the water. The ions present in the water obviously prevented bacterial growth. The water could be kept clean for weeks by using only mechanical filtering with a sand filter.

Table 1. Analysis of swimming pool water.

	Sample 1	Sample 2	Sample 3
Amount of dissolved solids mg/ml	214	182	166
Hardness in $CaCO_3$ mg/ml	100	62	104
Iron, Fe mg/ml	0.01	0.001	0.01
Chloride, Cl mg/ml	54	47	43
pH	7.1	7.1	7.0
Copper, Cu mg/ml	0.661	0.673	0.325
Manganese, Mn mg/ml	0.011	0.007	0.007
Sodium, Na mg/ml	18.0	11.9	14.6
Turbidity, NTU	1.9	0.57	0.43
Zinc, Zn mg/ml	1.92	3.31	1.74
Bacteria; coliform	-	-	-
Bacteria; non-coliform	-	-	-

The invention is not restricted to any one of the examples presented above, but many variations are possible within the inventive idea defined by the claims.

CLAIMS

1. Apparatus for electrical purification of water, said apparatus comprising a reaction chamber (1) provided with side walls (2), a bottom wall (3), a top wall (4) and a partition wall (5) dividing the reaction chamber into a first chamber (6) and a second chamber (7), each provided with a mainly vertical plate-shaped electrode (8), the partition wall and the electrodes being disposed at a distance from the bottom wall; an inlet (9) for the water to be purified; an outlet (10) for the purified water; a power source (11) and a gas outlet (12), characterized in that the inlet (9) for the water to be purified is located in a wall (2, 3, 4) of the first chamber (6) and the outlet (10) for the purified water is located in a wall (2, 3, 4) of the second chamber (7), so that the water to be purified can circulate freely from the first chamber (6) into the second chamber (7), washing the electrodes (8) and the reaction chamber (1).

2. Apparatus as defined in claim 1, characterized in that each one of the chambers (6, 7) contains at least two mainly plate-shaped electrodes (8).

3. Apparatus as defined in claim 1 or 2, characterized in that the reaction chamber (1) comprises two opposite, mainly parallel side walls (2) and that the electrodes (8) are placed at a sharp angle relative to these walls.

4. Apparatus as defined in any one of claims 1 - 3, characterized in that the electrodes (8) are mainly parallel to each other.

5. Apparatus as defined in any one of claims 1 - 4, characterized in that the electrodes (8) are composed of rod-shaped elements.

6. Apparatus as defined in any one of claims 1 - 5, characterized in that the electrodes (8) are made of zinc, copper, carbon, silver, graphi-

te, titan or the like.

7. Apparatus as defined in any one of claims 1 - 6, characterized in that all the electrodes (8) are made of the same material.

8. Apparatus as defined in any one of claims 1 - 6, characterized in that the electrodes (8) are made of different materials.

9. Apparatus as defined in any one of claims 1 - 8, characterized in that the electrodes (8) are attached to the top wall (4) so that they can be lifted up for cleansing.

10. Apparatus as defined in any one of claims 1 - 9, characterized in that the bottom wall (3) is provided with an electrically conductive bottom plate (13) serving to set up a homogeneous electric field.

11. Apparatus as defined in any one of claims 1 - 11, characterized in that the bottom plate is made of metal, preferably copper, stainless steel or the like.

12. Apparatus as defined in any one of claims 1 - 11, characterized in that the apparatus comprises a reverse osmosis filter (14).

13. Apparatus as defined in any one of claims 1 - 12, characterized in that the apparatus comprises an active carbon filter (15).

14. Apparatus as defined in any one of claims 1 - 13, characterized in that the apparatus comprises a centrifugal crystallizing/separating cyclone (16).

15. Apparatus as defined in any one of claims 1 - 14, characterized in that it is mainly of the shape of a parallelopiped and placed at an oblique angle, preferably a sharp angle, e.g. 45°, relative to the horizontal plane.

16. Apparatus as defined in any one of claims 1 - 15, characterized in that it is provided

with an ultrasonic device (17) to prevent undesirable crystallization of salt.

17. Procedure for electrical purification of water, in which the water to be purified is supplied via a water inlet into the reaction chamber of an electrical water purification apparatus, c h a r a c - t e r i z e d in that the water is first passed into a first chamber of the reaction chamber and then into a second chamber, so that the water circulates freely, washing the reaction chamber and electrodes placed in the reaction chamber.

18. Procedure as defined in claim 17, c h a - r a c t e r i z e d in that the purified water is passed out from the reaction chamber of the electrical water purification apparatus via an outlet and further into a reverse osmosis filter.

19. Procedure as defined in claim 17 or 18, c h a r a c t e r i z e d in that the purified water is passed out into an active carbon filter.

20. Procedure as defined in any one of claims 17 - 19, c h a r a c t e r i z e d in that any water not filtered by the reverse osmosis filter is passed into a centrifugal crystallizing/separating cyclone and then back into the purification process.

21. Procedure as defined in any one of claims 17 - 20, c h a r a c t e r i z e d in that the water to be purified is sea water.

22. Procedure as defined in any one of claims 17 - 21, c h a r a c t e r i z e d in that undesirable crystallization is prevented by means of an ultrasonic device.

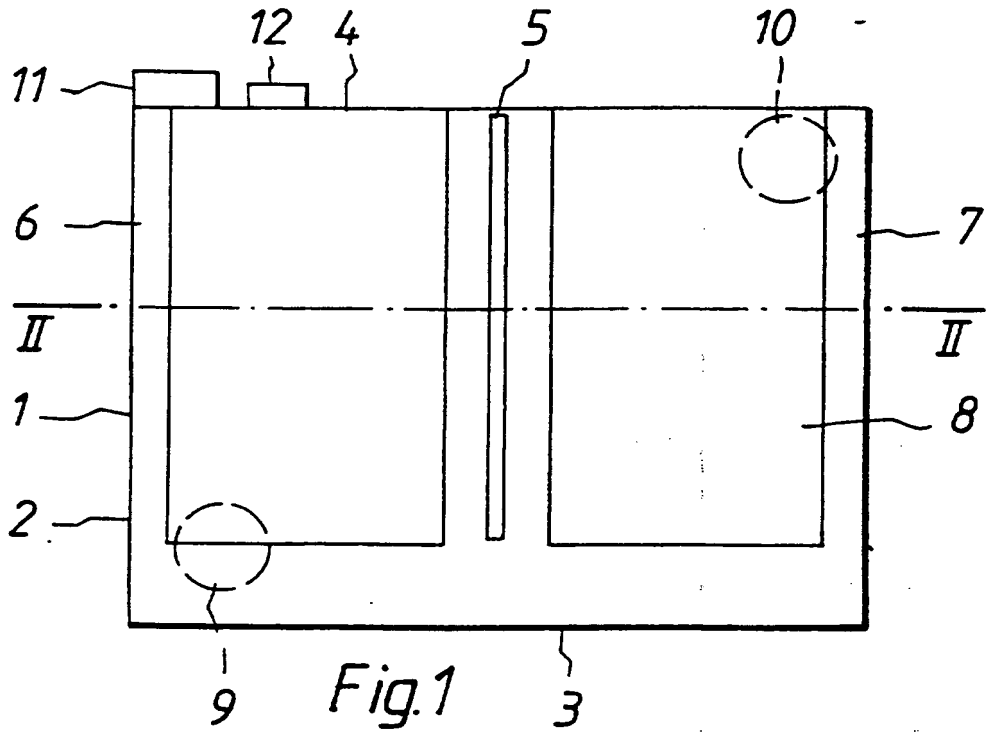

Fig.1

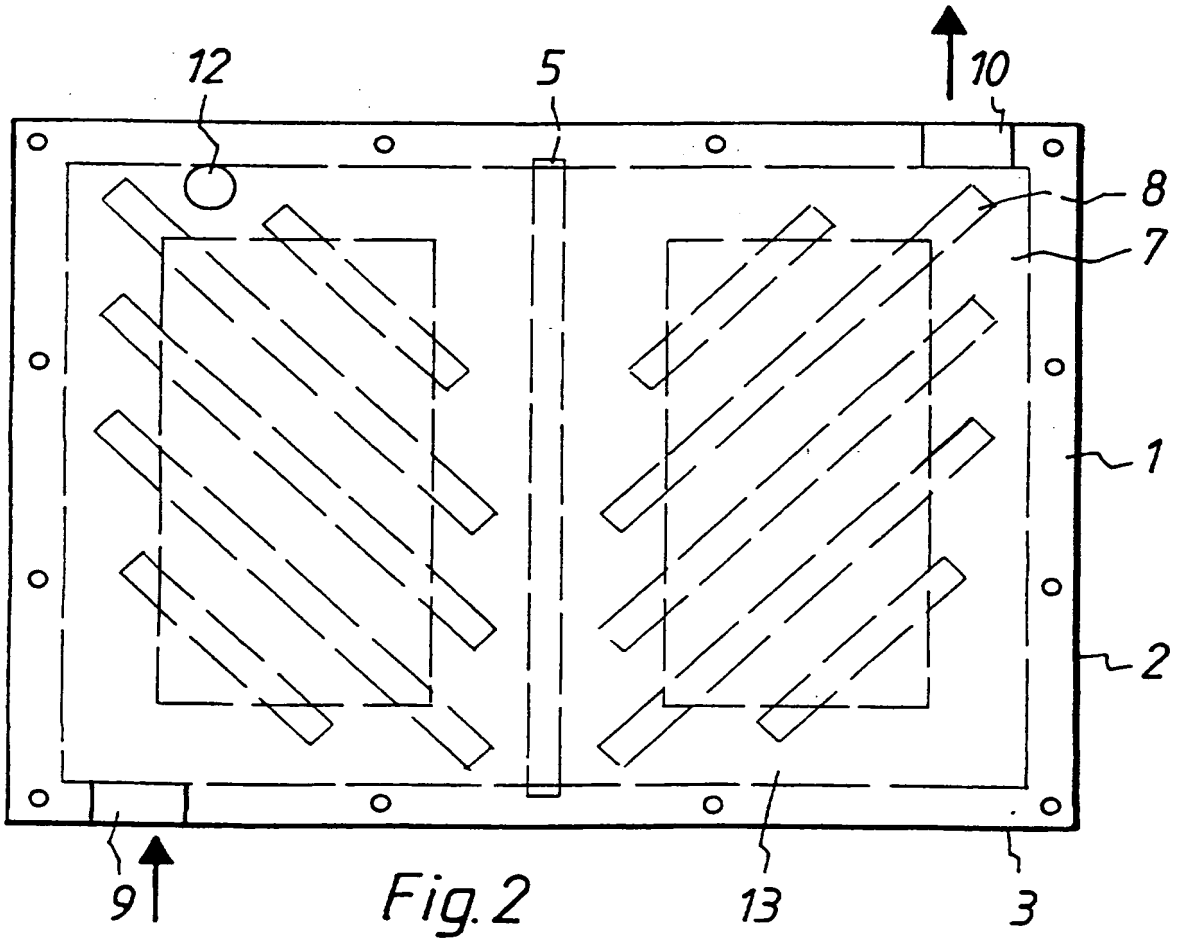

Fig.2

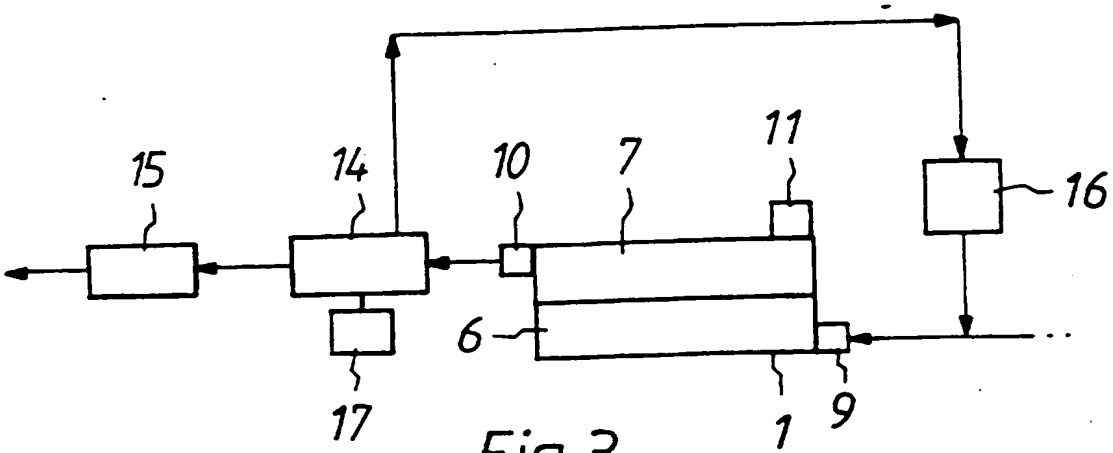

Fig.3

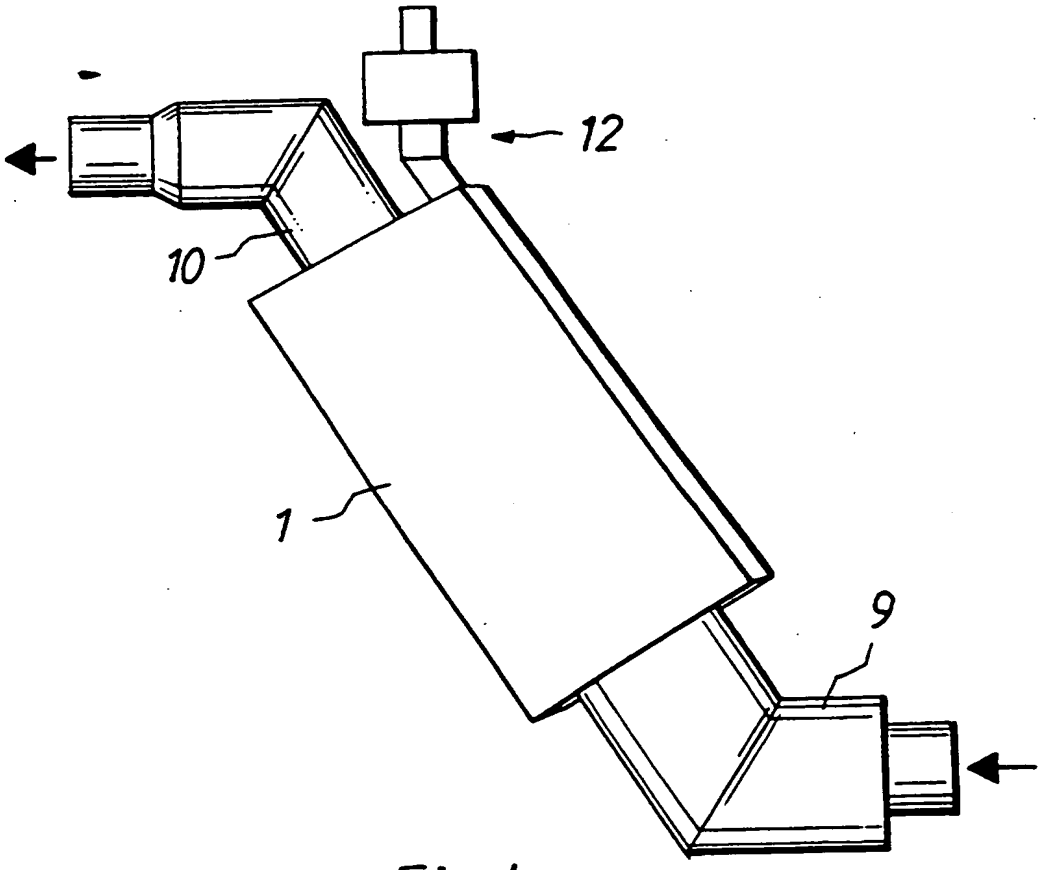

Fig.4

INTERNATIONAL SEARCH REPORT

In. .ational application No.
PCT 96/00591

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: C02F 1/46
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: C02F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

QUESTEL, EDOC, WPIL

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5227052 A (JUHANI E. ILVES), 13 July 1993 (13.07.93), column 3, line 28 - line 45; column 3, line 56 - column 4, line 2, figure 1, claims 1,2,4	1-2,6-8, 12-14,16-22
A	GB 2287718 A (NEC CORPORATION), 27 Sept 1995 (27.09.95), page 10, line 30 - page 11, line 2, figure 1	16,22
A	EP 0605882 A1 (NEC CORPORATION), 13 July 1994 (13.07.94), figure 1, abstract	1,17

[X] Further documents are listed in the continuation of Box C. [X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
6 March 1997	07 -03- 1997
Name and mailing address of the ISA/ Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. +46 8 666 02 86	Authorized officer Bengt Christensson Telephone No. +46 8 782 25 00

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI 96/00591

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0150381 A2 (VEREINIGTE ELEKTRIZITÄTSWERKE WESTFALEN AG), 7 August 1985 (07.08.85), figure 1, abstract --	1,17
A	EP 0612694 A1 (NIPPON INTEK CO., LTD.), 31 August 1994 (31.08.94), figure 1, abstract --	1,17
A	CH 675715 A5 (ASEA BROWN BOVERI AG), 31 October 1990 (31.10.90), figure 1, abstract --	1,17
A	EP 0054606 A1 (KERNFORSCHUNGSZENTRUM KARLSRUHE GMBH), 30 June 1982 (30.06.82), figure 2, claims 4-5 --	1,17
A	EP 0133920 A1 (OLIN CORPORATION), 13 March 1985 (13.03.85), figure 3, claims 8-10 -- --------	1,17

INTERNATIONAL SEARCH REPORT

03/02/97

Int[illegible]ional application No.
PCT[illegible] 96/00591

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